PCT/CA 2004/001567

05 OCTOBER 2004 05-10-0

Office de la propriété intellectuelle du Canada

Un organisme d'Industrie Canada

Canadian Intellectual Property Office

An Agency of Industry Canada

REC'D 03 NOV 2004

WIPO PCT

PCT/CA04/1567

Bureau canadien des brevets

Certification

Canadian Patent Office

Certification

La présente atteste que les documents ci-joints, dont la liste figure ci-dessous, sont des copies authentiques des documents déposés au Bureau des brevets.

This is to certify that the documents attached hereto and identified below are true copies of the documents on file in the Patent Office.

Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,439,487**, on September 4, 2003, by **OPTIMUM PRODUCTION TECHNOLOGIES INC.**, assignee of Glenn Wilde, for "Positive Pressure Gas Jacket for a Natural Gas Pipeline".

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

Agent certificateur/Certifying Officer

October 5, 2004

Date

Canada

(CIPO 68)
31-03-04

OPIC CIPO

BEST AVAILABLE COPY

POSITIVE PRESSURE GAS JACKET FOR A NATURAL GAS PIPELINE

FIELD OF THE INVENTION

The present invention relates to methods and apparatus for protecting against the influx of air into a pipeline carrying a combustible gas under negative pressure, and particularly to such methods and apparatus for use in association with a pipeline carrying natural gas under negative pressure from a natural gas well to a gas compressor.

BACKGROUND OF THE INVENTION

Natural gas is commonly found in subsurface geological formations such as deposits of granular material (e.g., sand or gravel) or porous rock. Production of natural gas from these types of formations typically involves drilling a well a desired depth into the formation, installing a casing in the wellbore (to keep the well bore from sloughing and collapsing), perforating the casing in the production zone (i.e., the portion of the well that penetrates the gas-bearing formation) so that gas can flow into the casing, and installing a string of tubing inside the casing down to the production zone. Gas can then be made to flow up to the surface through a production chamber, which may be either the tubing or the annulus between the tubing and the casing. The gas flowing up the production chamber is conveyed through an intake pipeline running from the wellhead to the suction inlet of a wellhead

compressor. The compressed gas discharged from the compressor is then conveyed through another pipeline to a gas processing facility and sales facility as appropriate.

When natural gas is flowing up a well, formation liquids will tend to be entrained in the gas stream, in the form of small droplets. As long as the gas is flowing upward at or above a critical velocity (the value of which depends on various well-specific factors), the droplets will be lifted along with the gas to the wellhead. In this situation, the gas velocity provides the means for lifting the liquids, and the well is said to be producing by "velocity-induced flow". Because liquids in the gas stream can cause internal damage to most gas compressors, a gas-liquid separator is provided in the intake pipeline to remove liquids from the gas stream before entering the compressor. The liquids may be pumped from the separator and reintroduced into the gas flow at a point downstream of the compressor, for eventual separation at the gas processing facility. Much more commonly, however, the liquids are collected in a tank on the well site.

In order to optimize total volumes and rates of gas recovery from a gas reservoir, the bottomhole flowing pressure should be kept as low as possible. The theoretically ideal case would be to have a negative bottomhole flowing pressure so as to facilitate 100% gas recovery from the reservoir, resulting in a final reservoir pressure of zero. In order to reduce the bottomhole pressure to a negative value, or to a very low positive value, it would be necessary to have a negative flowing pressure (i.e., less than atmospheric pressure) in the intake pipeline. This can be readily accomplished using well-known technology; i.e., by providing a wellhead compressor of sufficient power.

However, negative pressure in a natural gas pipeline would present an inherent problem, because any leak in the line (e.g., at pipeline joints) would allow the entry of air into the pipeline, because air would naturally flow to the area of lower pressure. This would create a risk of explosion should the air/gas mixture be exposed to a source of ignition. In addition to the explosion risk, entry of air into the pipeline also creates or increases the risk of corrosion inside the pipeline. For these reasons, the pressure in the intake pipeline is typically maintained at a positive level (i.e., higher than atmospheric). Therefore, in the event of a leak in the intake pipeline, gas in the pipeline will escape into the atmosphere, rather than air entering the pipeline. The explosion and corrosion risks are thus minimized or eliminated, but in a way that effectively limits the rate at which gas can be produced from the well.

One way of minimizing or eliminating the explosion and corrosion risks, while facilitating the use of negative pressures in the intake pipeline, would be to provide an oxygen sensor in association with the pipeline. The oxygen sensor would be adapted to detect the presence of oxygen inside the pipeline, and to shut down the compressor immediately upon detection of oxygen. This system thus would more safely facilitate the use of high compressor suction pressures so as to induce negative pressures in the intake pipeline and, therefore, to induce negative or low positive bottomhole flowing pressures. However, this system has an inherent drawback in that its effectiveness would rely on the proper functioning of the oxygen sensor. If the sensor malfunctions, and if the malfunction is not detected and remedied in timely fashion, the risk of explosion and/or corrosion will become

manifest once again. This fact highlights an even more significant drawback in that this system would not prevent the influx of air into the pipeline in the first place, but is merely directed to mitigation in the event of that undesirable event.

For the foregoing reasons, there is a need for an improved method and apparatus for minimizing and protecting against the risk of explosion arising from the influx of air into a pipeline carrying a combustible gas such as natural gas under negative pressure. There is a particular need for such methods and apparatus that do not require or rely on the use of oxygen sensors or other instruments or devices that are prone to malfunction. Even more particularly, there is a need for such methods and apparatus that prevent the influx of air into the pipeline in the first place. The present invention is directed to these needs.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described with reference to the accompanying figures, in which numerical references denote like parts, and in which:

FIGURE 1 is a schematic diagram of a well producing natural gas in accordance with prior art methods and apparatus.

FIGURE 2 is a schematic diagram of a well producing natural gas in accordance with a preferred embodiment of the method and apparatus of the present invention.

FIGURE 3 is a schematic diagram of a well producing natural gas in accordance with an alternative embodiment of the method and apparatus of the present invention.

BRIEF DESCRIPTION OF THE INVENTION

In general terms, the present invention provides a method and apparatus whereby the intake pipeline running between the production chamber of a natural gas well and the suction inlet of an associated wellhead compressor is completely enclosed, in airtight fashion, within a jacket of natural gas under positive pressure (i.e., higher than atmospheric). Being enclosed inside this "positive pressure jacket", the intake pipeline is not exposed to the atmosphere at any point. This allows gas to be drawn into the compressor through the intake pipeline under a negative pressure, without risk of air entering the intake pipeline should a leak occur in the pipeline. If such a leak occurs, there would merely be a harmless transfer of gas from the positive pressure jacket into the intake pipeline. If a leak occurs in the positive pressure jacket, gas therefrom would escape into the atmosphere, and entry of air into the positive pressure jacket would be impossible.

The present invention will be best understood after first reviewing conventional methods and apparatus for carrying natural gas from a well to a compressor. **FIG. 1** schematically illustrates a typical natural gas well **W** configured in accordance with prior art methods and apparatus. The well **W** penetrates a subsurface formation **F** containing natural gas (typically along with water and crude oil in some proportions). The well **W** is lined with a casing **20** which has a number of perforations conceptually illustrated by short lines **22**

within a production zone (generally corresponding to the portion of the well penetrating the formation **F**). As conceptually indicated by arrows **24**, formation fluids including gas, oil, and water may flow into the well through the perforations **22**. A string of tubing **30** extends inside the casing **20**, terminating at a point within the production zone. The bottom end of the tubing **30** is open such that fluids in the wellbore may freely enter the tubing **30**. An annulus **32** is formed between the tubing **30** and the casing **20**.

It should be noted that, to facilitate illustration and understanding of the invention, the Figures are not drawn to scale. The diameter of the casing **20** is commonly in the range of 4.5 to 7 inches, and the diameter of the tubing **30** is commonly in the range of 2.375 to 3.5 inches, while the well **W** typically penetrates hundreds or thousands of feet into the ground. It should also be noted that except where indicated otherwise, the arrows in the Figures denote the direction of flow within various components of the apparatus.

In the well configuration shown in **FIG. 1**, the tubing **30** serves as the production chamber to carry gas from the well **W**, under positive pressure, to an above-ground intake pipeline **40** which in turn carries the gas through a gas-liquid separator **70** to the suction manifold **42S** of a gas compressor **42**. A downstream pipeline **44** connects at one end to the discharge manifold **42D** of the compressor **42** and continues therefrom to a gas processing facility (not shown). As schematically indicated, liquids **72** separated from the gas flowing in the intake pipeline **40** will accumulate in a lower section of the separator **70**. In the usual case, the liquids **72** flow from the separator **70** to a storage tank **80** on the wellsite.

The present invention may be best understood from reference to **FIG. 2**. The invention provides for production of gas under negative pressure, in which case the liquids **70** removed from the gas stream by the separator **70** will also be under negative pressure, and for this reason a vacuum pump **74** is provided as shown. The liquids **72** flow under negative pressure through a pump inlet line **78** to the pump **74**, which pumps the liquids **72**, now under positive pressure, through a liquid return line **76** into the production pipeline **44** at a point **Z** downstream of the compressor **72**. Alternatively, the liquids **72** may be pumped to an on-site storage tank **80**.

As illustrated in **FIG.2**, the intake pipeline **40**, the separator **70**, and the pump inlet line **78** are fully enclosed by a vapour-tight positive pressure jacket **50** that defines a continuous internal chamber **52**. The positive pressure jacket **50** will typically be constructed of welded steel. However, suitable and well-known alternative materials may be used without departing from the fundamental concept and scope of the present invention.

A gas recirculation pipeline **60** extends between, and is in fluid communication with, the downstream pipeline **44** (at point **X** located between the compressor **42** and point **Y**) and the intake pipeline **40** (at point **Y** located between the compressor **42** and the separator **70**).

By means of the recirculation pipeline **60**, a portion of the gas discharged from the discharge manifold **42D** of the compressor **42** may be diverted into the positive pressure jacket **50**, such that the intake pipeline **40**, the separator **70**, the pump **74**, and the pump inlet line **78** are entirely enclosed by a "blanket" of gas under positive pressure. The positive

pressure jacket **50** thus enshrouds all components of the apparatus containing combustible fluids under negative pressure with a blanket of gas under positive pressure, thereby preventing the entry of air into the combustible fluids present in any of those components.

The embodiment shown in **FIG. 2** provides for what may be termed a "static" positive pressure blanket, as the gas inside the positive pressure jacket **50** will be essentially stationary. In an alternative embodiment of the invention, illustrated in **FIG. 3**, the internal chamber **52** of the positive pressure jacket **50** is in fluid communication with the annulus **32** of the well **W**, such that gas from the internal chamber **52** of the positive pressure jacket **50** can be injected into the annulus **32**. As shown schematically in **FIG. 3**, a pressure regulator valve **54** is provided to regulate the gas pressure inside the positive pressure jacket **50**. The pressure regulator valve **54** may be set such that it will open, thus allowing gas to enter the annulus **32**, only when the gas pressure in the internal chamber **52** of the positive pressure jacket **50** is above a selected value. Under either static conditions (as in **FIG. 2**) or gas injection conditions (as in **FIG. 3**), internal chamber pressures in the approximate range of 40 to 50 pounds per square inch are considered desirable. However, higher or lower pressures may be used without departing from the concept and principles of the present invention.

As schematically illustrated in **FIG. 3**, a throttling valve (or "choke") **62** optionally may be provided in association with the recirculation pipeline **60**, to regulate the flow of gas from the downstream production pipeline **44** into the recirculation pipeline **60** and thence into the internal chamber **52** of the positive pressure jacket **50** and ultimately into the well **W**.

Gas injection provides an additional benefit in that it enhances gas production from the formation F by further reducing bottomhole pressures in the well W. Formation pressures in virgin gas reservoirs tend to be relatively high. Therefore, upon initial completion of a well, the gas will commonly rise naturally to the surface provided that the characteristics of the reservoir and the wellbore are suitable to produce stable flow (meaning that the gas velocity at all locations in the production chamber remains equal to or greater than the critical velocity – in other words, velocity-induced flow).

However, as wells penetrate the reservoir and gas reserves are removed, the formation pressure drops continuously, inevitably to a level too low to induce gas velocities high enough to sustain stable flow. Therefore, all flowing gas wells producing from reservoirs with depleting formation pressure eventually become unstable. Once the gas velocity has become too low to lift liquids, the liquids accumulate in the wellbore, and the well is said to be "liquid loaded". This accumulation of liquids results in increased bottomhole flowing pressures and reduced gas recoveries. Injection of recirculated gas, as provided for by the present invention, can be effective to prevent or alleviate liquid loading, by effectively increasing the upward velocity of the gas stream in the production chamber so as to maintain a gas velocity at or above the critical velocity for the well in question, thus maintaining velocity-induced flow. The effectiveness of gas injection for this purpose is described in further detail in the present Applicant's Canadian Patent Application No. 2,242,745, filed on April 9, 2003.

Although not illustrated, it will be appreciated that the gas injection embodiment shown in **FIG. 3** can be readily adapted for use in association with a gas well in which the annulus **32** serves as the production chamber. In that case, the intake pipeline **40** will be in fluid communication with the annulus **32**, and the internal chamber **52** of the positive pressure jacket **50** will be in fluid communication with the bore of the production tubing **30**. Accordingly, pressurized gas diverted into the internal chamber **52** will be injected into the well **W** through the tubing **30**, with the same production-enhancing benefits as described previously in connection with embodiments wherein the tubing **30** serves as the production chamber.

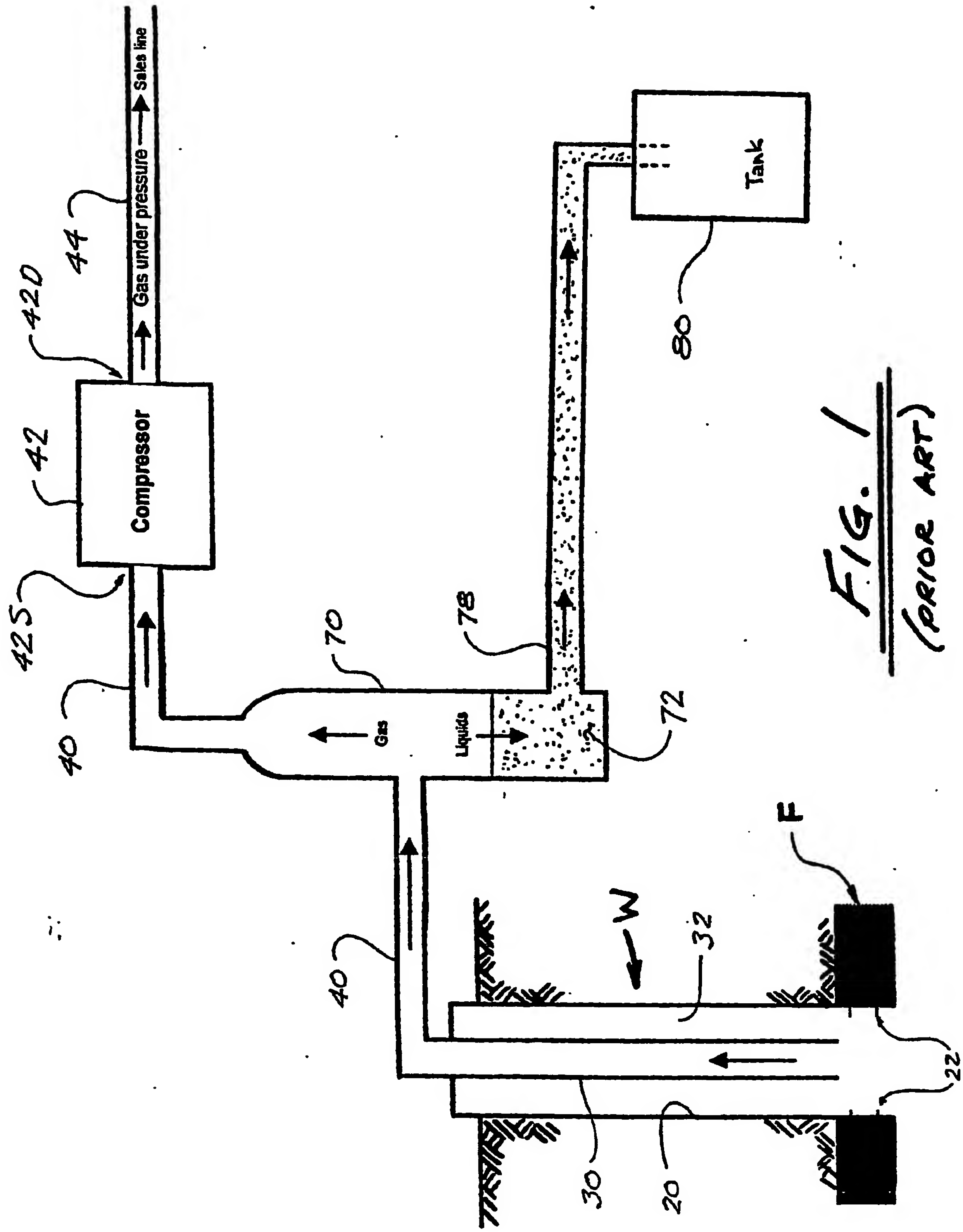

FIG. 1
(PRIOR ART)

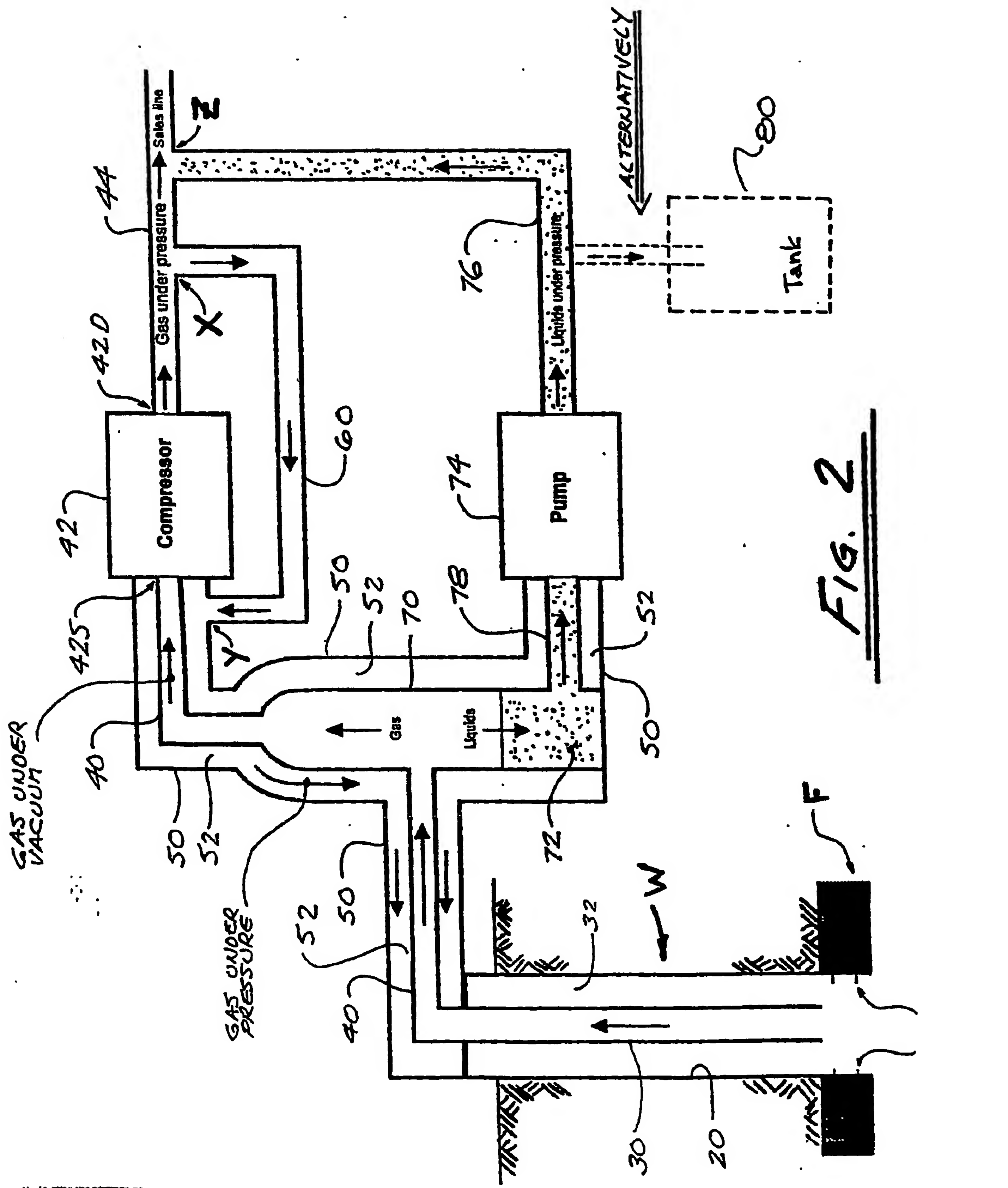
Compressor
Pump
Tank
Gas under pressure
Sales line
Liquids under pressure
Gas
Liquids
GAS UNDER VACUUM
GAS UNDER PRESSURE
ALTERNATIVELY
X
Y
Z
W
F
20
30
32
40
42
42D
42S
44
50
52
60
70
72
74
76
78
80

FIG. 2

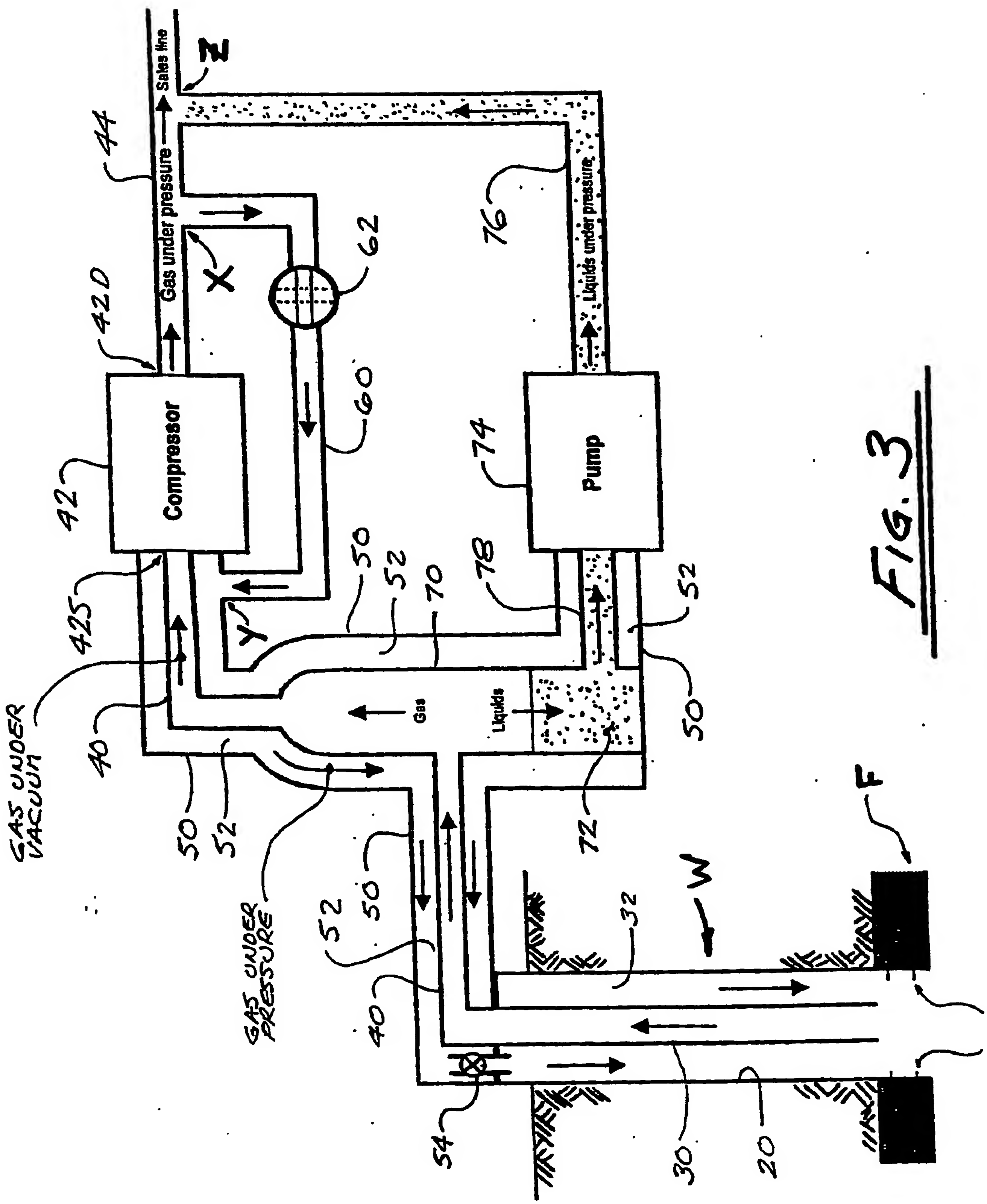
Sales line
Gas under pressure
Liquids under pressure
Compressor
Pump
Gas
Liquids
GAS UNDER VACUUM
GAS UNDER PRESSURE
Z
X
Y
W
F
44
42D
42
42S
62
60
76
74
78
70
50
52
40
72
54
30
20
32

FIG. 3

Box No. VIII (iv) DECLARATION: INVENTORSHIP (only for the purposes of the designation of the United States of America)
The declaration must conform to the following standardized wording provided for in Section 214; see Notes to Boxes Nos. VIII, VIII (i) to (v) (in general) and the specific Notes to Box No. VIII (iv). If this Box is not used, this sheet should not be included in the request.

Declaration of inventorship (Rules 4.17(iv) and 51*bis*.1(a)(iv)) for the purposes of the designation of the United States of America:

I hereby declare that I believe I am the original, first and sole (if only one inventor is listed below) or joint (if more than one inventor is listed below) inventor of the subject matter which is claimed and for which a patent is sought.

This declaration is directed to the international application of which it forms a part (if filing declaration with application).

This declaration is directed to international application No. PCT/.......................... (if furnishing declaration pursuant to Rule 26*ter*).

I hereby declare that my residence, mailing address, and citizenship are as stated next to my name.

I hereby state that I have reviewed and understand the contents of the above-identified international application, including the claims of said application. I have identified in the request of said application, in compliance with PCT Rule 4.10, any claim to foreign priority, and I have identified below, under the heading "Prior Applications," by application number, country or Member of the World Trade Organization, day, month and year of filing, any application for a patent or inventor's certificate filed in a country other than the United States of America, including any PCT international application designating at least one country other than the United States of America, having a filing date before that of the application on which foreign priority is claimed.

Prior Applications: ....

....

I hereby acknowledge the duty to disclose information that is known by me to be material to patentability as defined by 37 C.F.R. § 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the PCT international filing date of the continuation-in-part application.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name: WILDE, Glenn

Residence: Calgary, Alberta, CANADA
(city and either US state, if applicable, or country)

Mailing Address: 9541 - 21 Street SE, Calgary, Alberta, CANADA, T2C 4G1

Citizenship: Canadian

Inventor's Signature: Glenn Wilde
(if not contained in the request, or if declaration is corrected or added under Rule 26*ter* after the filing of the international application. The signature must be that of the inventor, not that of the agent)

Date: 18 August 2004
(of signature which is not contained in the request, or of the declaration that is corrected or added under Rule 26*ter* after the filing of the international application)

Name: ....

Residence: ....
(city and either US state, if applicable, or country)

Mailing Address: ....

....

Citizenship: ....

Inventor's Signature: ....
(if not contained in the request, or if declaration is corrected or added under Rule 26*ter* after the filing of the international application. The signature must be that of the inventor, not that of the agent)

Date: ....
(of signature which is not contained in the request, or of the declaration that is corrected or added under Rule 26*ter* after the filing of the international application)

☐ This declaration is continued on the following sheet, "Continuation of Box No. VIII (iv)".